The use of 3D scanners in military technology

Zastosowanie skanerów 3D w technice wojskowej

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In the article is presented a method to identify geometry of military objects based on 3D scanning technology and photogrammetric processes. During the scanning process different types of markers and calibrated patterns of length, placed on the object are used. Results of measurements using three different methods: base points measurementare method, 3D scanning method and 3D scanning in conjunction with the measurement geometry characteristic points method.
KEYWORDS: military vehicle, 3D scanning, strain identification, photogrammetry

Damage to technical facilities, including military ones, causes local changes in the shape of the product, and their size and nature are directly related to the impact that has caused the damage. In general, the initial state of the object can be determined from the production records or measurements of new objects. However, to assess the extent of damage, to qualify the object for further repair, and to select the appropriate repair methods and technologies, it is necessary to know the exact condition of the object after the damage. Such a possibility is provided by 3D scanning techniques and photogrammetric methods [1, 3, 4].

The purpose of the study was to present the usefulness of 3D scanners for the identification of military vehicle damage using various optical methods such as photogrammetric baseline measurement, 3D structural light imaging, and hybrid scanning - 3D scanning combined with geometry of feature points (bases) .

Shape recovery methods

Damage to military facilities in many cases is related to the destructive effect of explosive energy, resulting in a change in its geometric dimensions. There are several optical methods for mapping shapes of military objects. The most commonly used are:
- measurement of characteristic points using the photogrammetric technique,
- 3D scanning using structural light,
- 3D scanning using laser,
- method combining 3D scanning with a photogrammetric method.

Photogrammetric technique - base points

In many situations, when identifying damage to military vehicles, it is not necessary to determine the geometry of the whole object; the geometry of the characteristic points – bases – should be just designated. Depending on the situation, the whole or part of the object, such as the floor plate, the connecting points of the body with the undercarriage, may be subject to evaluation.

During the study, TRITOP photogrammetric system (by GOM) was used to measure the geometry of the base points.

This system can be used to assess the degree of the structure deformation of the object to be measured after the failure as well as to assess the accuracy of assembly of the individual components. For most measuring points, the device allows to receive measurement results fairly quickly.

After properly defining the base points for measuring length, width and height, individual adapters (Figure 1a) must be placed in characteristic points of the object to define the measurement points.

All important points of the object are marked with marks, and then the subject is photographed at different camera angles. The size of a truck requires a large number of shots. In the case of the examined object, 164 shots were taken which were subjected to photogrammetric analysis.

A set of base points has been extracted, which has been scaled based on the distance declared using the pattern lengths. By comparing the measurement results with the CAD model of the examined object, information about the location of the individual points and the deviation of those points from the CAD model in the *X, Y, Z* planes was obtained. Once the maximum permissible dimensional differences have been defined, the suitability of the object for further operation can be automatically determined by defining the maximum differences between the coordinates of the measured point and the coordinates of the CAD model.

a) *b)*

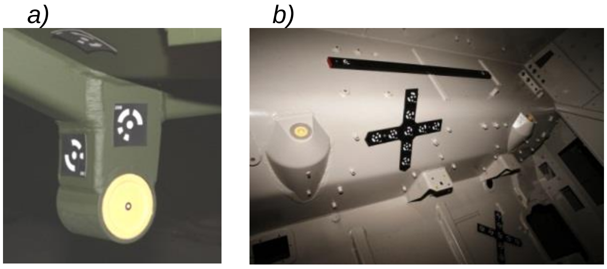

Fig. 1. Measurement of military vehicle base points: *a)* example of the adapter attachment to determine the base points, *b)* length pattern and coded points

Fig. 2 shows an example of the base points measurement results of an undercarriage frame of a military vehicle. The measured points without comparing them with the nominal values are given. This is very common when it is important to know the individual dimensions of an object without having to refer them to specific values, e.g. when measuring objects of unknown dimensions. Depending on the mode of operation selected, the measurement results may be in the form of actual dimensions that are derived from the base points

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established by the plane or the difference between actual and the manufacturer's specifications.

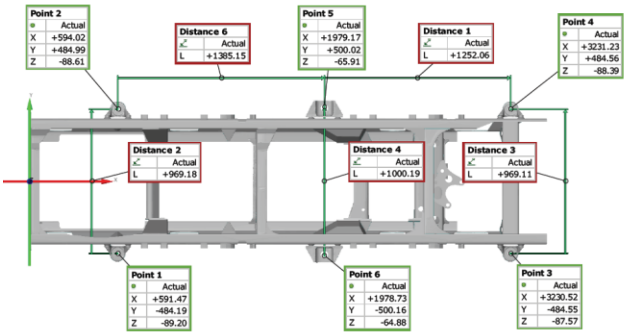

Fig. 2. Results of base points measurement - special vehicle frame [2]

Scanning method using structural light

In many cases, the measurement of the base point geometry is not sufficient to correctly identify the object's deformation. In this case, a 3D scan of the entire surface of the object should be applied.

The object processing unit consists of a device projecting onto a test object a number of bands, whose image on an uneven surface is distorted according to the shape of the surface. The coordinates of the points on the measured surface are determined by triangulation. The accuracy of the scan depends on the size of the area and the scanner configuration used.

Since scanning of an object involves multiple measurements of surfaces from different sides and angles, the reference points are applied to the object, which allows for the orientation of the surface in space and the joining of images. The photogrammetric system TRITOP is used to measure the position of the reference points.

Due to the limited area of a single surface "seen" by the camera, it is necessary to scan the surface multiple times with the sliding camera and to scan at different angles to reach the invisible areas at one camera setting.

As a result of multiple scans of successive surfaces of a solid, there are a number of images that are then linked together. Surface scanning with camera shifts and body scan at various angles allows for the removal of hollow areas that may be invisible due to large surface deformations (they are visible in the images as blank, "transparent" areas). Then, in the process of polygonization, the images are joined together. Overlapping areas are removed. The processed point cloud can be transformed into a grid of triangles, which can then be imported into external programs such as MES. When comparing the objects images with each other or with CAD data, a color map of deviations is generated.

Scanning large surfaces allows to reproduce the full body of a vehicle. Proper placement of marks within the object allows to determine even the thickness of a sheet, the object was made from. Thickness of elements can also be introduced into the program separately.

Sheet metal deformation caused by various impacts can be assessed by assuming the flatness of a single plate and calculating the deviation between the scanned object and the "applied" plane (Fig. 3). It is also possible to compare the deviation of the entire scanned surface of a vehicle with the CAD model of an object or the image of a scanned surface of another vehicle assumed as a model object.

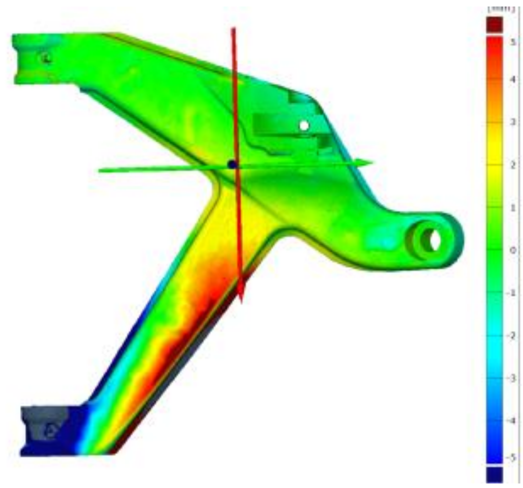

Fig. 3. Deformation assessment - comparison of real object and CAD model - map of deviations

Combined method - combination of 3D scanning with photogrammetric method

When there is no possibility or need to scan the entire object to measure its geometry, but for analysis it is necessary to determine the size - in the form of object dimensions and shapes - a combined method can be used, where part of dimensions are removed by scanning the surface by means of 3D scanner, while other dimensions (planes) are created on a base of measurement of characteristic points using a photogrammetric set.

An example of such a procedure is the measurement of the C-130 Hercules cargo hold to check the load capacity of the truck. This task required the development of an airplane cargo space model. The model of the C-130 aircraft interior was done by 3D scanning and by measuring the characteristic points and determining the individual curves on them (Fig. 4).

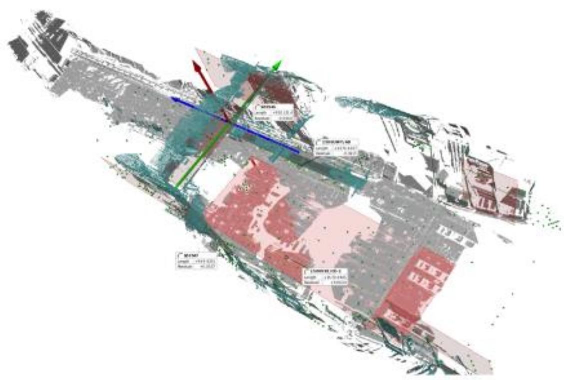

Fig. 4. Combined method of measuring the of C-130 airplane interior - combined scanned areas and aircraft internal planes [3]

Conclusions

The results show the suitability of 3D scanning for the analysis of deformation and dimensioning of even very large objects of complex shapes, which would be difficult, time-consuming or impossible to analyze by classical methods.

With the developed and used adapter set with reference points, the photogrammetric method can be used to identify the position of large object's base points.

Using the presented methods, quality control, deformation measurement, manufacturing and repairing errors, the accuracy of the fit by virtual assembly in the software, and surface changes due to damage, can be performed.

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